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HIGH VELOCITY SPECTROSCOPIC BINARY ORBITS FROM PHOTOELECTRIC RADIAL VELOCITIES: BD +82 565 A

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Abstract. The spectroscopic orbit of a circumpolar high proper motion visual binary BD +82 565 A component is determined from 57 CORAVEL radial velocity measurements. A short period $P = 12.69$ d and a moderate eccentricity $e = 0.30$ are obtained. The visual system AB has a projected spatial separation ~ 830 AU. The system's barycenter velocity $V_0 = -86.7$ km/s, the transverse velocity $V_t = 118.7$ km/s and the Galactic spatial velocity components $U = -62.6$ km/s, $V = -84.1$ km/s and $W = -84.2$ km/s give evidence that it belongs to the thick disk of the Galaxy.

Key words: stars: binaries: spectroscopic, visual, individual: BD +82 565

1. INTRODUCTION

In 1988 we initiated a program of photoelectric radial velocity measurements of Population II single and binary stars (Bartkevičius & Sperauskas 1990, 1994, 1999, 2005; Bartkevičius et al. 1992; Sperauskas & Bartkevičius 2002). The analysis of the results have led to the discovery of some new radial velocity variables. With this publication we start to publish spectroscopic orbits of the newly discovered binaries.

As a high proper motion star ($\mu = 0.37''$per year), BD +82 565 was first mentioned in 1916 (communicated by the Astronomer Royal, MNRAS, 76, 585). Its proper motion was determined by comparing the coordinates given in vol. III of the Greenwich Astrographic Catalogue with the coordinates from the Circumpolar Stars Catalogue (Carrington 1857). Luyten included this star in his high proper motion catalogs LTT (Luyten 1961) and NLTT (Luyten 1979). The star is also included in the Lowell Observatory high proper motion survey as G 259-37, and there a very good identification chart is given (Giclas et al. 1970). As a double common proper motion star, it was discovered by Luyten (1966). Slightly different data are given in subsequent Luyten's publications (Luyten 1967, 1968). The star is also included in the original Luyten publication of Double Stars with Common Proper Motion (LDS) as LDS 1894 (Luyten 1969). In NLTT Luyten gives the angular distance $d = 12.0''$ and $PA = 81.0°$ between the A and B components. Salim & Gould (2003) in the Revised NLTT Catalogue presents slightly

different values for the AB system: $d = 11.5''$ and $PA = 87.9°$ for J2000.0. Our estimates using the CDS ALADIN interactive sky atlas are: $d = 11.2 \pm 0.2''$, $PA = 79.5 \pm 0.7°$ for J1950.0 and $d = 11.4 \pm 0.1''$ $PA = 82.9 \pm 0.3°$ for J2000.0. To our knowledge, no other measurements of angular distance and position angle between the components are known.

2. IDENTIFICATION

Equatorial coordinates of the A component of the binary are $\alpha(2000.0) = 18^{\rm h}47^{\rm m}02.6389^{\rm s}$, $\delta(2000.0) = +82° \ 43' \ 30.260''$. Five stars are seen in one arcmin field of the first Palomar Observatory Sky Survey (POSS I) (Figure 1). In the second-epoch Palomar survey the third star is blended by the binary due to its high proper motion (Figure 2). Identification of the stars taken from the CDS Simbad is presented in Table 1. Stars 3, 4 and 5 are optical components.

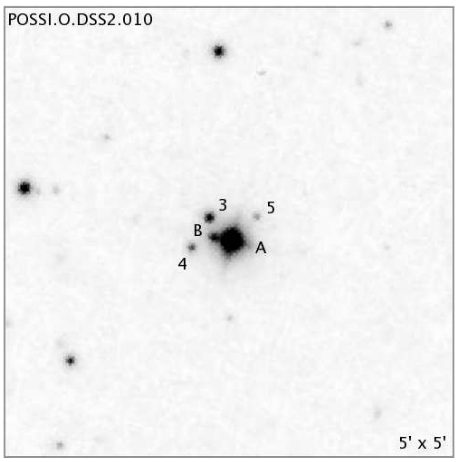

Fig. 1. Identification chart from the first Palomar Observatory Sky Survey (POSS I.O).

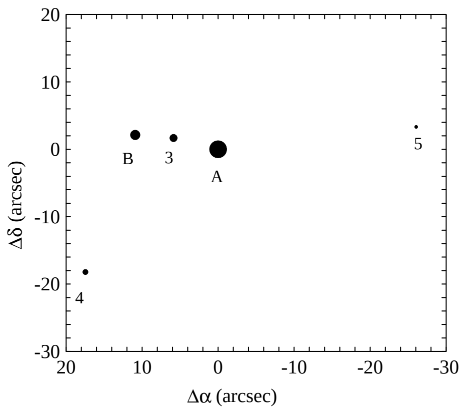

Fig. 2. Identification chart for epoch 2000.0. Proper motion for star 3 is unknown, its position is for the epoch 1953.7.

Table 1. Identification of binary components and nearby stars.

Component A
BD +82 565, AGK3 +82 545, HIP 92162, PLX 4424, CCDM J18471+8244, WDS J18470+8244, IDS 18587+8236, PPM 3296, SAO 3127, G 259-37, LTT 15562, LDS 1894, TYC 4648 474 1, USNO-A2.0 1725-00600458, GSC2.2 N01001337626, 2MASS 18470262+8243300
Component B
LP 10-124, LP 9-323, 2MASS 18470873+8243320
Star 3
USNO-A2.0 1725-00600531
Star 4
USNO-A2.0 1725-00600574, GSC2.2 N01001337627, APM-N EO0802-0246683, 2MASS 18471195+8243116
Star 5
USNO-A2.0 1725-00600367, APM-N EO0802-0246181, GSC2.2 N01001337628

3. PHOTOMETRY AND SPECTRAL TYPES

From the Kharchenko (2001) ASCC-2.5 catalog the magnitude and color index of the A component are: $V = 9.32 \pm 0.02$ and $B–V = 0.67 \pm 0.04$. The B component and other three field stars have only photographic magnitudes in the systems similar to B and R, and they are presented in Table 2. The infrared 2MASS photometry results available for three stars are also given.

Table 2. Photometry of stars in the vicinity of BD +82 565.

Comp.	B	σ_B	R	σ_R	$B–R$	$\sigma_{(B-R)}$	Source
A	9.99	0.03	8.81	0.41	1.18	0.41	ASCC-2.5, GSC2.2
B	16.0		14.5		1.5		NLTT
3	16.0		14.7		1.3		USNO-A2.0
4	17.12	0.41	15.29	0.42	1.91	0.59	GSC2.2
5	17.60	0.41	17.15	0.42	0.45	0.59	GSC2.2

Comp.	J	σ_J	H	σ_H	K	σ_K	$J–H$	$\sigma_{(J-H)}$	$H–K$	$\sigma_{(H-K)}$
A	8.085	0.026	7.773	0.023	7.694	0.018	0.312	0.035	0.079	0.029
B	11.455	0.022	10.949	0.019	10.761	0.023	0.506	0.029	0.188	0.030
4	14.092	0.027	13.487	0.025	13.451	0.050	0.605	0.037	0.036	0.056

Three discrepant one-dimension spectral types for the A component are known. Petersson (1927) in 1924 classified the star as F8 using 264 Å/mm dispersion objective prism spectra obtained at the Uppsala Observatory. This type is given in the Skiff (2003) *Catalogue of Stellar Spectral Classifications*. G. P. Kuiper obtained a considerably later spectral type, K0 (published by Bidelman (1985) in the article "G. P. Kuiper's spectral classifications of proper-motion stars"). A decade earlier Bidelman & Lee (1975) presented Kuiper's spectral type in a compilation of spectral types for proper motion stars pointing Jenkins (1952) *Catalogue of Trigonometric Parallaxes* as the literature source. In the van Altena et al. (1995) catalog of trigonometric parallaxes a dK0 spectral class is given, quoting Bidelman as the literature source, so the origin of the dwarf classification is not clear. The third spectral class, G0, was estimated by Balz (1958) from the McCormick Observatory 300 Å/mm spectra, and quoted also in the AGK3 catalog and in many other sources including the SIMBAD database. Intrinsic color index $(B-V)_0 = 0.65$ corresponds to the G2/G5 V spectral type. For the B component Luyten presented different color classes: from k, k-m to m. 2MASS colors correspond to a dwarf of K5–K7 spectral type.

4. DISTANCE, ABSOLUTE MAGNITUDE AND KINEMATICS

Hipparcos recorded a good precision (6%) parallax $\pi = 13.78 \pm 0.81$ mas. This corresponds to a distance d of 72.6 ± 4.3 pc. Only one useless ground-based parallax, $\pi = 0.0017 \pm 0.0133$ mas, measured with the Greenwich Observatory Thompson 66 cm refractor (Dyson 1925) is included in Jenkins (1952) and van Altena et al. (1995) Yale General Parallax Catalogues. The *Tycho* program obtained a very negative parallax, $\pi = -9.90 \pm 11.20$ mas. Kharchenko (2001), following a questionable method to average *Hipparcos* and *Tycho* parallax determinations, has presented $\pi = 13.65 \pm 0.81$ mas. From Schlegel et al. (1998) interstellar reddening

maps for the binary at $\ell = 114.8^\circ$ and $b = 27.0^\circ$ the total line-of-sight interstellar reddening is $E_{B-V} = 0.07$. Taking into account a distance to the binary of 72.6 pc (from the *Hipparcos* parallax), the true $E_{B-V} = 0.02$ and $A_V = 0.07$ are calculated (Anthony-Twarog & Twarog 1994).

The absolute magnitude of component A from the *Hipparcos* parallax and the above-mentioned V and A_V is $M_V = 4.95 \pm 0.13$ mag. In the M_V vs. $(B-V)_0$ plot the A component is situated within the main-sequence band. The reduced proper-motion diagram H_V, B–V places the star at the subdwarf-main sequence border. The B component in the blue spectral region is fainter by 6 mag, in the red – by 5.7 mag, and this corresponds to a M3/4 dwarf. However, the infrared 2MASS photometry of the star is consistent with an earlier K5/7 dwarf.

The *Hipparcos* parallax, the *Tycho 2* proper motion components and our value of spectroscopic binary barycenter radial velocity are used to calculate kinematical parameters of the system. The procedure of computation is the same as in Bartkevičius & Gudas (2001, 2002). The velocity component U is directed to the Galactic center, V – to the direction of Galactic rotation and W – to the North Galactic Pole. They have been corrected due to the solar motion with respect to the Local Standard of Rest $U = 10.0 \pm 0.4$ km/s, $V = 5.2 \pm 0.6$ km/s and $W = 7.2 \pm 0.4$ km/s (Binney & Merrifield 1998). Evidently, the binary belongs to the thick disk population.

5. RADIAL VELOCITY MEASUREMENTS

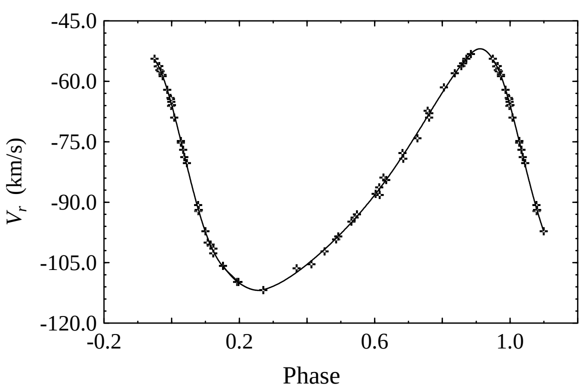

Fig. 3. Radial velocity curve.

Radial velocity measurements were made by J. Sperauskas with a CORAVEL-type spectrometer constructed at the Vilnius University Observatory. A description of the measurements and data reduction procedures are presented in Upgren, Sperauskas & Boyle (2002). 57 individual radial velocities for BD +82 565 A were obtained at the Molėtai Observatory with the 0.63 m and 1.65 m telescopes. These measurements were spread over the period of 619 days starting in 2000 August 28. Standard single-measurement errors range from 0.7 to 1.0 km/s with the mean value of 0.8 km/s. Individual radial velocity measurements are listed in Table 4 together with the Heliocentric Julian Days and phases calculated from the orbital elements, measurement errors and residuals.

6. ORBITAL SOLUTION

The obtained radial velocity curve is plotted in Figure 3. The calculated orbital elements are given in Table 5. The system has a high center of mass radial velocity and moderate orbit eccentricity.

Table 3. Kinematical parameters.

ℓ	b	μ_α	$\sigma\mu\alpha$	μ_δ	$\sigma\mu\delta$	V_r	σV_r	V_t
degr	degr	mas	mas	mas	mas	km/s	km/s	km/s
114.8	27.0	183.3	1.5	292.3	1.5	–86.70	0.07	118.7
σ_{V_t}	U	σ_U	V	σ_V	W	σ_W	$V_{\rm tot}$	$\sigma_{V_{\rm tot}}$
km/s	km/s	km/s	km/s	km/s	km/s	km/s	km/s	km/s
7.0	–62.6	3.2	–84.1	2.8	–84.2	1.2	147.0	5.6

Table 4. Radial velocity measurements.

HJD	Phase	V_r km/s	σV_r km/s	$O-C$ km/s	HJD	Phase	V_r km/s	σV_r km/s	$O-C$ km/s
51785.320	0.486205	–99.2	0.7	–0.195	52145.555	0.870708	–54.4	0.7	–0.047
51794.348	0.197561	–109.8	0.8	0.377	52147.289	0.007337	–69.0	0.8	–0.852
51999.586	0.369167	–106.4	0.8	1.009	52147.539	0.027036	–75.2	0.8	–0.402
52003.557	0.682060	–77.8	0.9	0.791	52179.320	0.531201	–94.8	0.7	0.198
52004.561	0.761169	–67.9	0.7	0.268	52180.361	0.613226	–86.3	0.8	0.360
52007.564	0.997789	–64.4	0.8	0.755	52181.266	0.684535	–79.2	0.8	–0.918
52007.569	0.998183	–66.1	0.8	–0.826	52182.234	0.760808	–69.0	0.8	–0.782
52007.576	0.998735	–65.1	0.9	0.342	52199.226	0.099682	–97.2	0.8	–0.031
52007.605	0.001020	–65.9	1.0	0.244	52203.200	0.412811	–105.4	0.7	–0.748
52008.583	0.078081	–90.7	0.9	0.818	52204.209	0.492315	–98.5	0.7	–0.016
52008.589	0.078553	–92.2	1.1	–0.546	52205.610	0.602706	–87.9	0.8	–0.094
52008.603	0.079656	–92.0	0.9	–0.033	52207.180	0.726413	–74.1	1.5	-1.225
52008.609	0.080129	–91.9	0.9	0.201	52207.563	0.756591	–67.3	1.4	1.496
52032.330	0.949211	–54.4	0.7	0.070	52208.578	0.836568	–58.0	0.9	0.040
52032.455	0.959061	–56.3	0.7	–0.386	52210.188	0.963427	–56.2	0.8	0.477
52032.556	0.967019	–57.5	0.8	–0.138	52210.195	0.963978	–57.2	0.8	–0.421
52033.321	0.027297	–74.8	0.7	0.088	52210.310	0.973040	–58.4	0.8	0.222
52033.405	0.033915	–77.0	0.7	0.186	52210.315	0.973434	–58.7	0.8	0.010
52033.449	0.037382	–78.8	0.8	–0.412	52210.484	0.986750	–62.1	0.8	–0.107
52033.545	0.044947	–80.3	0.7	0.692	52375.594	0.996494	–64.1	0.8	0.666
52034.329	0.106721	–100.0	0.7	-1.230	52377.566	0.151877	–105.8	0.9	0.561
52034.437	0.115231	–100.5	0.8	0.048	52382.585	0.547346	–93.0	0.8	0.463
52034.534	0.122874	–102.7	0.7	–0.699	52383.580	0.625746	–83.9	0.8	1.367
52034.539	0.123268	–101.5	0.8	0.572	52386.568	0.861184	–55.5	0.8	–0.240
52089.473	0.451760	–102.2	0.8	–0.401	52398.540	0.804511	–61.5	0.7	0.713
52141.368	0.540796	–93.8	0.8	0.292	52399.554	0.884408	–53.2	0.7	0.082
52142.305	0.614626	–88.2	0.8	-1.694	52403.478	0.193598	–109.8	0.7	0.166
52142.549	0.633852	–84.5	0.7	–0.153	52404.457	0.270737	–111.8	0.7	–0.588
52145.367	0.855895	–56.2	0.7	–0.390					

Table 5. Orbital elements of BD +82 565A.

Parameter	Value
Orbital period	P = 12.6913±0.0009 days
Center-of-mass velocity	V_0 = –86.70±0.07 km/s
Half-amplitude	K = 29.55±0.10 km/s
Eccentricity	e = 0.305±0.003
Longitude of periastron	$\omega = (57.3\pm0.6)^\circ$
Date of conjunction	$T_{\rm conj}$ = 2452401.021±0.022 HJD
Projected semimajor axis	$a \sin i = (4.91\pm0.02)\,10^6$ km
Function of the mass	$f(m) = 0.0294\pm0.0004\ M_\odot$
Mean square error of one observation	$\sigma_(O-C) = \pm$ 0.44 km/s

7. VISUAL SUBSYSTEM PARAMETERS

The period of the AB subsystem of almost 17 000 years is estimated using Kepler's third law, assuming circular face-on orbit, apparent separation $d = 11.5''$, parallax $\pi = 13.78$ mas and total mass 1.8 $M_\odot$, adopting for a spectroscopic binary A the main component $M = 1\ M_\odot$ (according to its spectral class) and for the secondary component 0.5 $M_\odot$ (from the spectroscopic mass function $f(m)$ taking $\sin^3 i = 2/3$). For the visual B component we adopted 0.3 $M_\odot$ (from the mass-luminosity relation). From the Palomar first and second epoch Sky Surveys and 2MASS survey crude estimates of the angular separation and position angle were made for two epochs. For $E_{\rm mean} = 1953.7$ we obtain: $d_{\rm mean} = (11.18 \pm 0.21)''$ and $PA_{\rm mean} = (79.65 \pm 0.69)^\circ$ and for $E_{\rm mean} = 1998.1$ we obtain $d_{\rm mean} = (11.46 \pm 0.07)''$ and $PA_{\rm mean} = (83.07 \pm 0.33)^\circ$. Evidently, during 44 years the angular separation practically did not change. Only the change of the position angle of 0.077° per year may be real. In case of the circular orbit, this change of PA corresponds to a period of about 4700 years which is almost four times smaller than that calculated from the third Kepler law.

The minimum spatial distance between components A and B, adopting the projected spatial distance from the mean angular separation $d = 11.4''$ and a distance of 72.6 pc, is ~ 830 AU.

8. CONCLUSIONS

A short-period ($P = 12.69$ d) and moderate eccentricity ($e = 0.30$) spectroscopic orbit of the A component of a high velocity ($v_{\rm tot} = 147.0$ km/s) visual binary system BD +82 565 is determined from 57 CORAVEL-type radial velocity measurements. The projected spatial separation of components of the visual binary AB is ~ 830 AU.

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